



# **US LHC Accelerator Research Program**

*bnl - fnal- lbl - slac*

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## **TQC structure scale up for LQC**

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*LARP Long Quadrupole (LQ) Mechanical Structure Review  
November 28-29, 2007*



# Introduction

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From ‘*Criteria for the Review of the LQ Magnet Structure*’

5. Understanding and addressing of length scale-up issues

**What are the LQC length scale-up issues?**

**How will they be addressed?**



# LQC Scale-up Issues

- **Scale up issues:**

- » Long coil handling, measuring and shimming - LM
- » **4 coil handling, assembly** and ground insulation
- » **Coil alignment**
- » **Collaring and handling**
  - » Collared coil OD measurement and pre-stress control
  - » Collared coil warm magnetic measurements
  - » Yoke ID measurement
  - » Collared coil shimming
  - » Cold mass instrumentation
- » **Skin welding - LM**
- » End plates welding, splicing, bullet pre-load
- » **Transportation - LM**
- » **Cold test – LM**

## Legend:

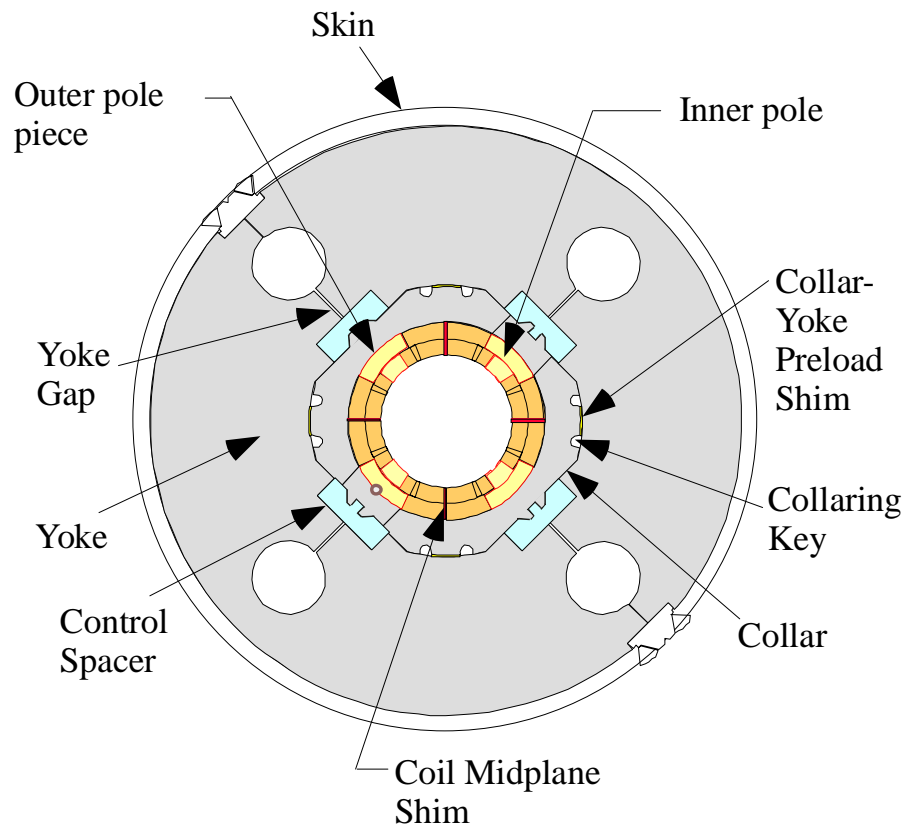
**plan in place**

addressed

understood-TQC



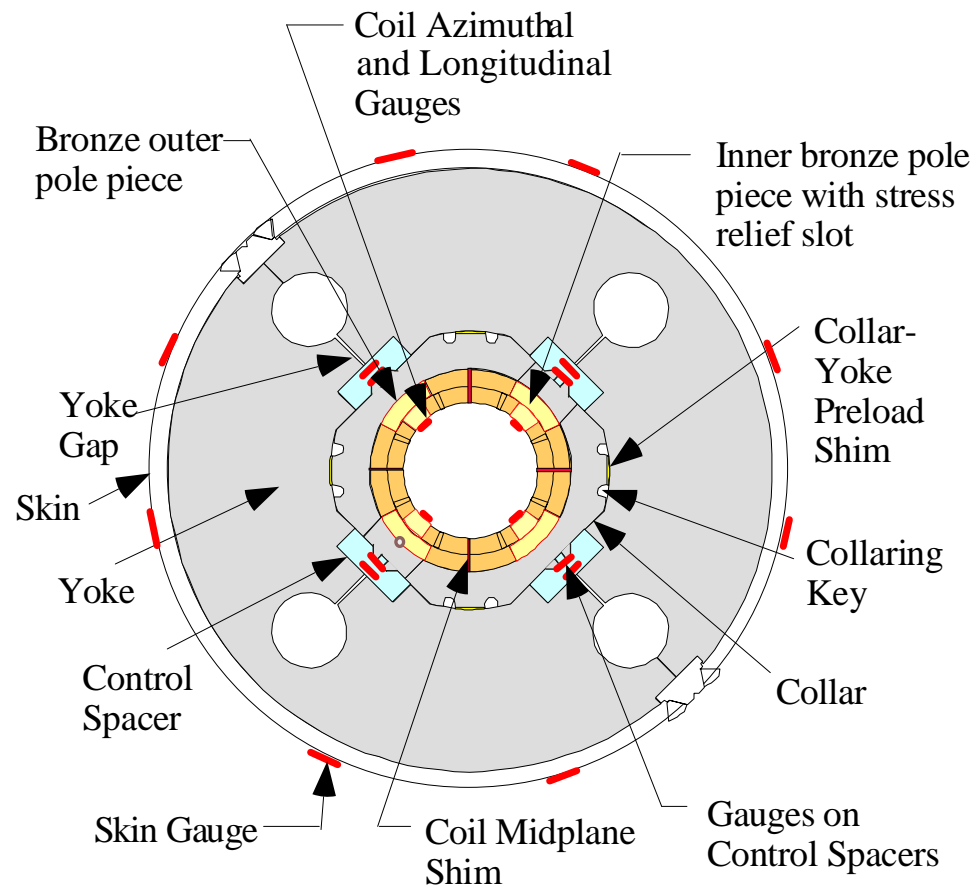
# LQC Mechanical Structure



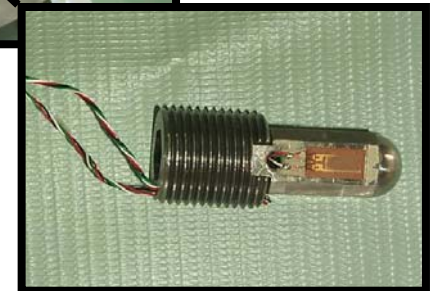
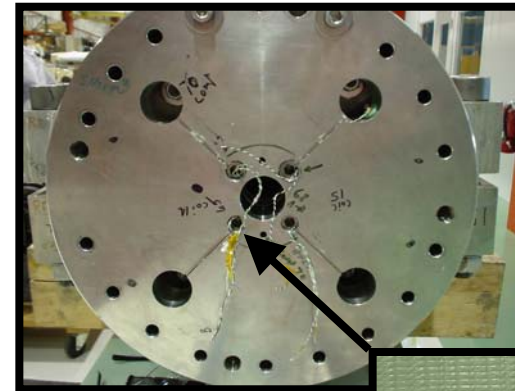
- Nitronic 40 SS collars with phosphor bronze keys  
→ initial coil preload
- SS control spacers interface with collar & yoke  
→ coil alignment  
→ yoke gap control
- Shell welding key and 12 mm thick shell  
→ remaining coil preload and alignment
- 50 mm SS end plate  
→ 14 kN total end load to coils via bullets



# LQC Instrumentation



- Voltage taps, strain gauges and RTD's.  
→ starting point is identical to TQC





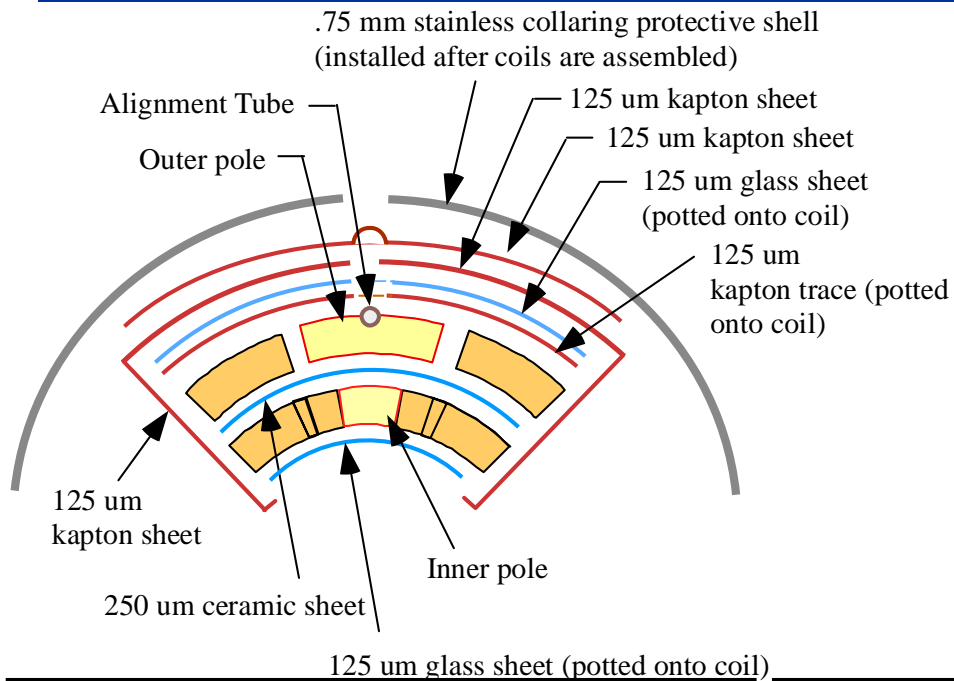
# LQC In-Process Measurements

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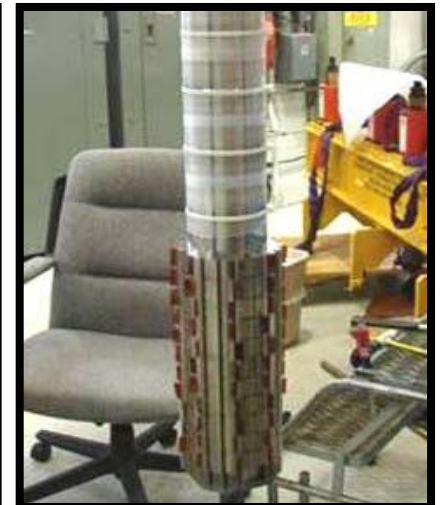
- Same as TQC
  - Coil Cross Section Measurements (used for mid-plane shim)
  - Collar Outside Diameter Measurements (coil preload & collar-yoke shim)
  - Yoke Inside Diameter Measurements (collar-yoke shim)
  - Monitoring of Coil Strain Gauges during collaring and yoking
  - Monitoring of strain gauges on structure during shell welding
  - Monitoring of end preload gauges during and after applying end load
  - Monitoring of coil resistance during all phases of assembly
  - Hi-potting at critical steps: After collaring, yoking, end preload, and at final electricals prior to shipment to VMTF.



# Coil Assembly



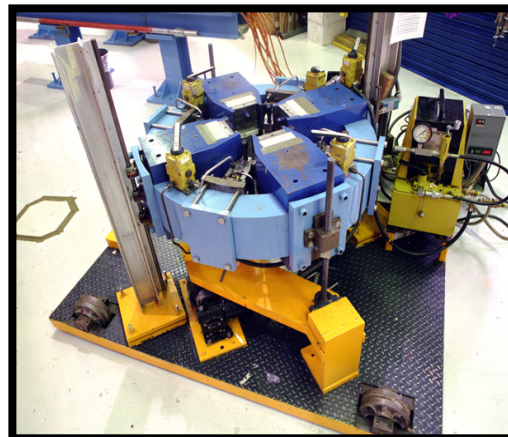
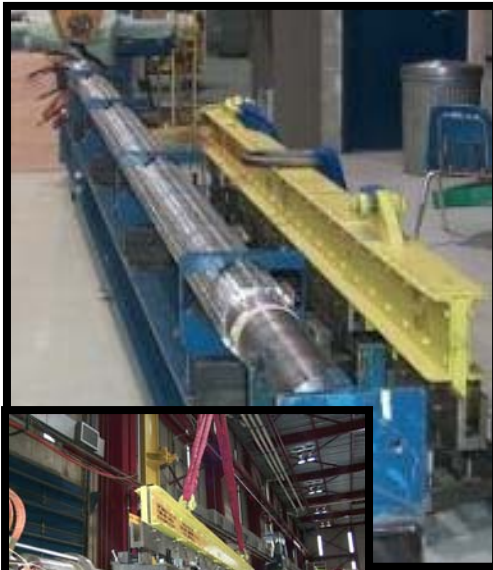
- Shims and ground insulation applied to coils then placed on assembly mandrel.
- .75 mm SS collaring shell is added
- 4 coil assembly tightly wrapped with mylar film
- Process is similar to MQXB; the cold mass used in the LHCIR Q2a/b.







# LQC Collaring



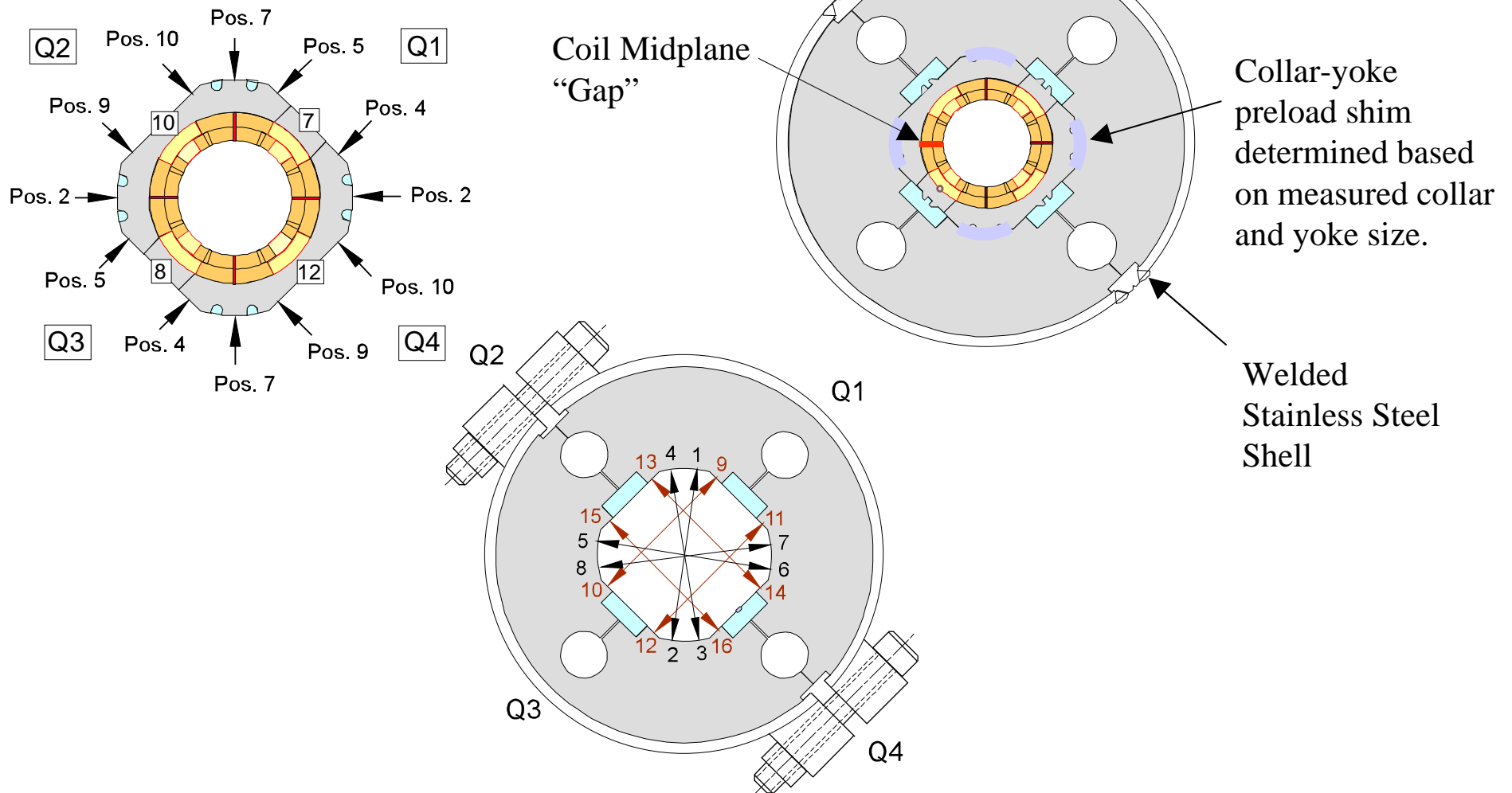
- Coil assembly is up righted. The process used is similar to MQXB and Tevatron HGQ.
- Collar keying is done in 5-6 passes while coil strain gauges are monitored
- Coil is brought to horizontal using the up right process in reverse
- Collared coil deflection is measured
  - verify preload
  - determine collar-yoke shim size





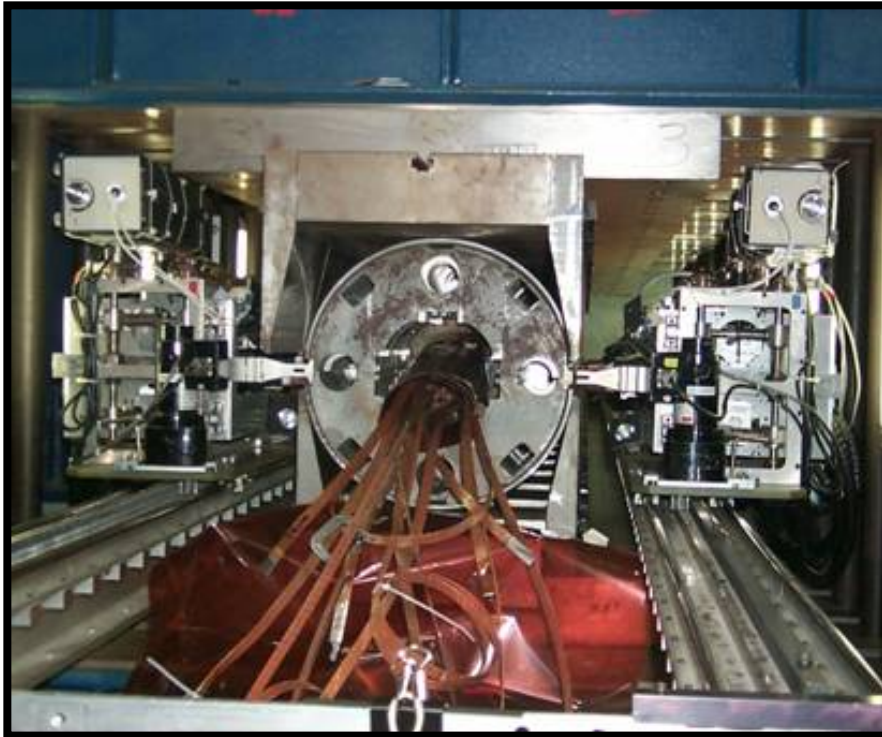
# Yoke ID & Collar-Yoke Shim

- Same as TQC





# Yoke and Shell Welding



- The lower instrumented shell place on weld press insertion table
- Lower yoke stacks, collar-coil assembly, upper yoke stack, and shell
- Roll into press
- Prepare for welding
- Process used for TQC, LM02 (4m dipole), and MQXB.



# Final Assembly

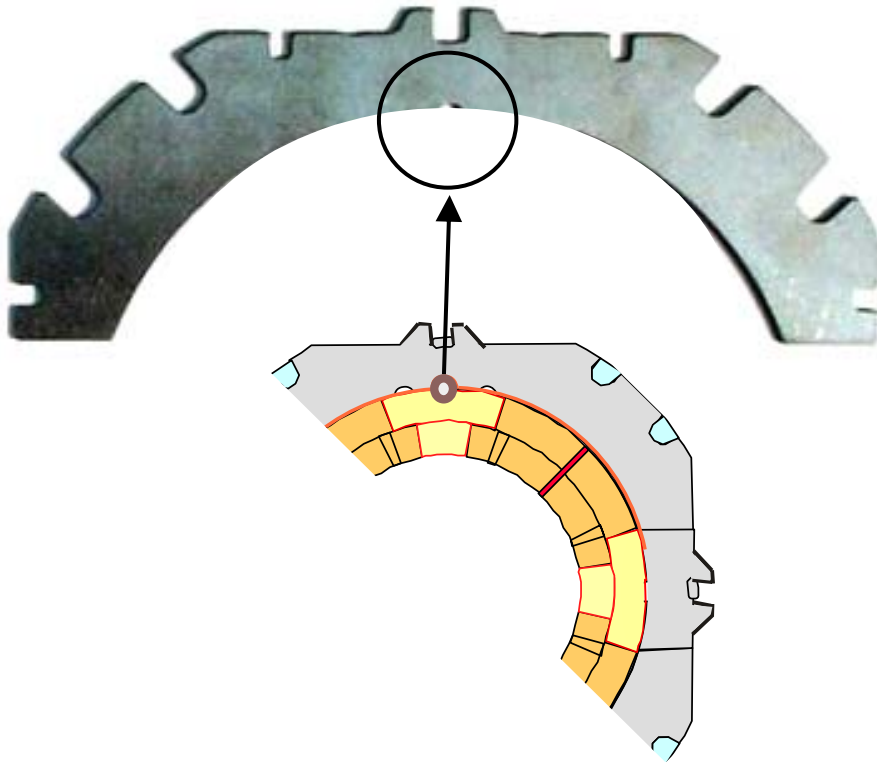


- Electricals
- Install bullet pressure plate
- Weld end plates
- Quadrant splice assembly
- Terminate wires to connectors
- Final electricals
- Magnetic measurements
- TEST!



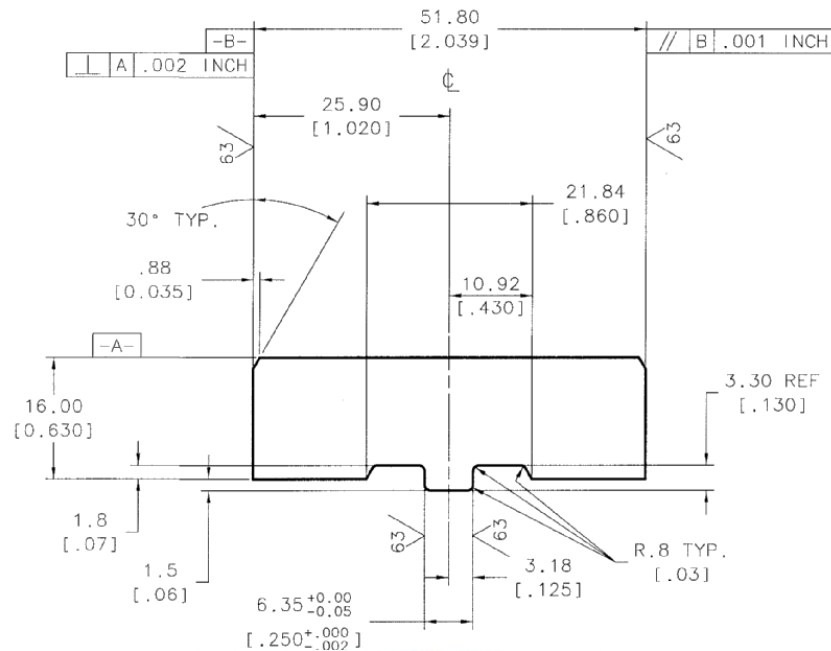
# LQC Coil-Collar Alignment

- Outer pole pieces have a round notch machined into them, which will fit a round notch in the collar laminations. A G-10 tube will be placed into the notch, providing azimuthal alignment between collars and coils.





# LQC Collar - Yoke Alignment

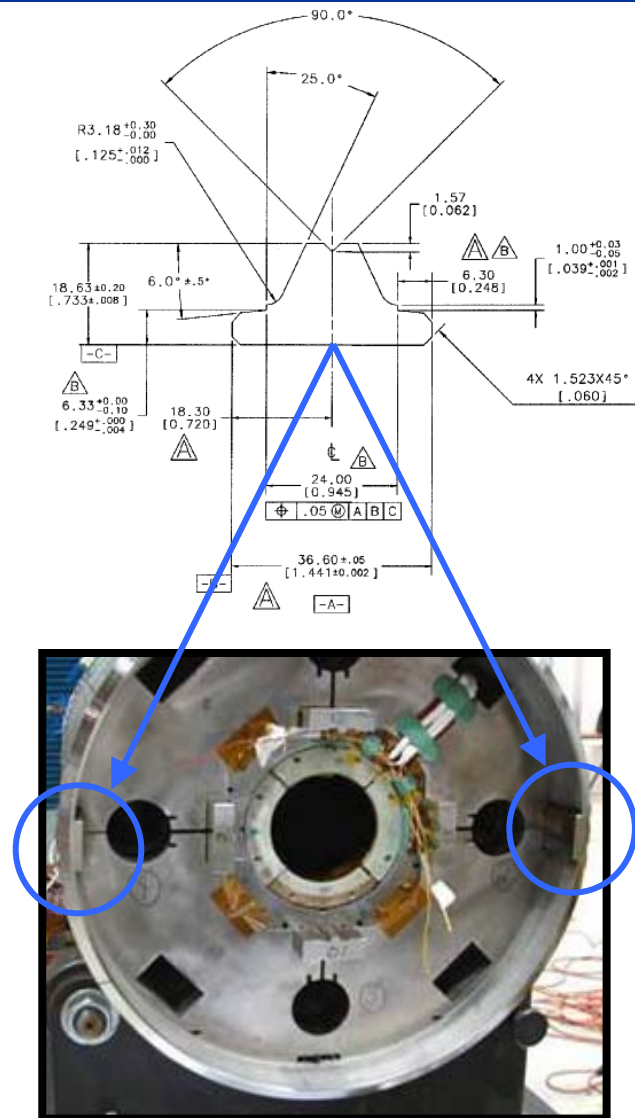


- The collar-yoke alignment is achieved with the control spacer tab and the collar feature used for collar alignment for the MQXB.





# Yoke – Shell Alignment



- The yoke is aligned to the shell via the shell welding alignment key. This is the same technique that was used for MQXB.
- Shell welding key also used to measure cold mass twist.





# LQ Coils

1<sup>st</sup> Cured LQ Practice Coil



- Identical geometric cross section to TQ magnet
- Aluminum bronze wedges, water cut and machined end parts
- Titanium poles and Ti pole ends (keys, nose pieces)
- 1<sup>st</sup> LQ practice coil winding & curing (photos left)
- Winding of 2<sup>nd</sup> practice coil underway
- Reaction scheduled start January 3, 2008



# LQ Coils

Cured TQ coils ready  
for shipment to LBNL



1<sup>st</sup> Cured LQ Practice Coil



- Several TQ coil pairs have been wound and cured at Fermilab, reacted and impregnated at LBNL, then shipped back to FNAL.
- This process has demonstrated that shipment of  $\text{Nb}_3\text{Sn}$  coils can be routinely achieved without damage.
- The process will be repeated with BNL reacting and impregnating coils for the first LQ magnet.



# LQC To Do's

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- Finalize coil handling & shipping tooling.
  - cured coils
  - potted coils
- Complete coil assembly station.
- Begin coil up-righting tooling design.
  - vertical support structure
  - dolly
- Procure long lead magnet parts during the 1<sup>st</sup> half of FY08.
- Procure remaining LQ magnet parts in 2<sup>nd</sup> half of FY08 as money becomes available.



# Conclusions



- Demonstrated an understanding and have addressed length scale-up issues.
- TQ mechanical structure ready for scale-up.
- TQC structure is compatible with the LARP length scale up goals and requirements
- Structure length scale up for LQC builds on experiences from long cold masses like MQXB, LBQ, and LM01/02.
- Excellent results in first practice coil winding and curing using scale up tooling.